

SEMI F53-0120

TEST METHOD FOR EVALUATING THE ELECTROMAGNETIC SUSCEPTIBILITY OF MASS FLOW CONTROLLERS

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1 Purpose

1.1 The purpose of this Document is to define a structured method for testing and evaluating the electromagnetic susceptibility of mass flow controllers (MFCs).

2 Scope

2.1 This Document contains the requirements and test method that can be used to evaluate whether an MFC will maintain its functional characteristics when subjected to electromagnetic interference (EMI) levels typical of the industry. The test method covers both the radiated susceptibility (RS) and conducted susceptibility (CS) of the MFC when exposed to EMI. The electromagnetic susceptibility requirements are extracted from MIL-STD-461G, and the test method is a composite of the RS103, and CS106 test methods defined in MIL-STD 461G.

NOTICE: SEMI Standards and Safety Guidelines do not purport to address all safety issues associated with their use. It is the responsibility of the users of the Documents to establish appropriate safety and health practices, and determine the applicability of regulatory or other limitations prior to use.

3 Limitations

3.1 This Test Method is not designed for AC-powered MFCs. The test method addresses electromagnetic susceptibility of MFCs through direct current (DC) power leads and control signals.

4 Referenced Standards and Documents

4.1 *IEEE Standard*¹

IEEE C63.14 — American National Standard Dictionary of Electromagnetic Compatibility (EMC) Including Electromagnetic Environmental Effect (E3)

4.2 *Military Standard*²

MIL-STD-461G — Requirements for the Control of Electromagnetic Interference Characteristics of Subsystems and Equipment

NOTICE: Unless otherwise indicated, all documents cited shall be the latest published versions.

5 Terminology

5.1 *Abbreviations and Acronyms*

5.1.1 *CS* — conducted susceptibility

5.1.2 *dB* — decibel

5.1.3 *DC* — direct current

5.1.4 *EMC* — electromagnetic compatibility

5.1.5 *EMI* — electromagnetic interference

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² United States Military Standards, Available through the Naval Publications and Forms Center, 5801 Tabor Avenue, Philadelphia, PA 19120-5099, USA; Telephone: +1.215.697.3321.

5.1.6 *GHz* — gigahertz

5.1.7 *kHz* — kilohertz

5.1.8 *kPa* — kilopascal

5.1.9 *MFC* — mass flow controller

5.1.10 *MHz* — megahertz

5.1.11 *psia* — pound-force per square inch absolute

5.1.12 *psig* — pound-force per square inch gauge

5.1.13 *RF* — radio frequency

5.1.14 *rms* — root mean square

5.1.15 *RS* — radiated susceptibility

5.1.16 *T* — tesla

5.1.17 *V* — volt

5.1.18 *V/m* — volt/meter

5.2 Definitions

5.2.1 *conducted susceptibility (CS)* — equipment vulnerability to conducted emissions.

5.2.2 *electromagnetic compatibility (EMC)* — the capability of electronic equipment or systems to be operated in the intended operational electromagnetic environment at designed levels of efficiency.

5.2.3 *electromagnetic interference (EMI)* — impairment of a wanted electromagnetic signal by an electromagnetic disturbance.

5.2.4 *ground* — a conducting connection, whether intentional or accidental, by which an electric circuit or piece of equipment is connected to the earth, or to some conducting body of relatively large extent.

5.2.5 *limit* — the level of susceptibility that a stated standard allows.

5.2.6 *noise (electrical)* — unwanted electrical signals that can produce undesirable effects in the circuits of control systems in which they occur.

5.2.7 *radiated susceptibility (RS)* — equipment vulnerability to radiated emissions.

5.2.8 *stable* — the state a signal level obtains when its magnitude varies by less than or equal to $\pm 2.0\%$ of full scale of the device under test over a one minute period.

6 Summary of Method

6.1 This Test Method describes the test equipment and procedures for determining if the mass flow controller is susceptible to radiated or conducted interference. Initially, the MFC is exposed to radiated electric fields over a frequency range from 10 kHz to 1 GHz at field strength levels less than 10 volts/meter (V/m). Furthermore, the MFC's power leads will be tested for susceptibility to voltage transients with 10 μ s rise times. See flow chart of the test method, Figure 1.

7 Apparatus

7.1 *Radiated Electric Field Susceptibility (RS103)*

7.1.1 *Signal Generator* — 10 kHz to 1 GHz.

7.1.2 *Audio Power Amplifier* — 10 kHz to 1 MHz.

7.1.3 *RF Power Amplifier #1* — 1 MHz to 400 MHz.

7.1.4 *RF Power Amplifier #2* — 500 MHz to 1 GHz.

7.1.5 *Field Strength Meter*

7.1.6 Oscilloscope

7.1.7 *Parallel Element Antenna* — 10 kHz to 20 MHz.

7.1.8 *Biconical Antenna* — 30 MHz to 200 MHz.

7.1.9 *Conical Log Spiral Antenna* — 300 MHz to 1 GHz.

7.1.10 *Tripod*

7.1.11 *Coaxial Cable, 15 m (50 ft.), RG-58* — With BNC male plugs at each end.

7.1.12 *X10 Attenuator Scope Probe*

7.1.13 *Assorted Coax Cables for Interconnects*

7.1.14 *Flow Standard* — Installed in series with the flow through the MFC, with accuracy better than that of the MFC.

7.1.15 *Flow Output Monitor* — Connected to the MFC output and signal common/ground points. The monitor/recorder shall be capable of measuring over a range of 0 to 10 VDC to within ± 5 mV. For MFCs with only digital output, the monitor/recorder shall be connected to the digital output of the MFC.

7.2 *Transient Susceptibility of Power and Control Leads (CS-106) (CS)*

7.2.1 *Spike Generator* — With series and parallel outputs.

7.2.2 *Oscilloscope* — Dual channel.

7.2.3 *X100 Scope Attenuator Probe* — Two each.

7.2.4 *Test Leads* — 30.48 cm (12 in.) long with banana plugs at each end, four each.

7.3 Apparatus required for both radiated and conducted tests.

7.3.1 *Test Gas Delivery System* — Capable of satisfying the test volume flow rate at a constant pressure of ± 0.7 kPa (± 0.1 psia) and at ambient temperature $\pm 1^\circ\text{C}$ for the duration of each analysis. The ambient temperature shall be held to $22^\circ\text{C} \pm 1^\circ\text{C}$.

8 Reagents and Materials

8.1 *Test Gas* — UHP grade Nitrogen with a dew point of less than or equal to -40°C and at a source delivery pressure of 342 kPa (35 psig).

9 Technical Precautions

9.1 The user must have a working knowledge of the respective instrumentation, must practice proper handling of test components, and must understand good laboratory practices.

9.2 These tests are to be performed in a shielded or screened room to prevent possible problems with nearby instrumentation or electrical systems caused by the electromagnetic fields. At a minimum, the instrumentation associated with this test series (see Figure 3) must be shielded from the electromagnetic fields to ensure their proper operation.

10 Calibration and Standardization

10.1 For each test, verify that calibration of test equipment is up-to-date. If any calibration is required during the performance of this procedure, such calibration shall be done in accordance with manufacturers' specifications.

11 Procedure

11.1 Install the MFC into the test setup per manufacturer's recommendations.

11.2 Apply power to all devices shown in Figure 3 per manufacturer's specifications. Allow the devices to warm up for the duration specified by the equipment manufacturer.

11.3 Purge the system with nitrogen for a length of time equal to ten times the amount of time it takes to replace the system volume once, when the test MFC is at its full-scale rated flow rate.

11.4 Close inlet shut-off valve. Then close the outlet shut-off valve located adjacent to the MFC (see Figure 2). Adjust the MFC setpoint to zero flow. Wait for the signals to become stable. Record the following on the data sheet:

- MFC indicated flow,
- Flow standard flow,
- Ambient temperature,
- Gas temperature, and
- Gas pressure.

11.5 Open the inlet and outlet shut-off valves adjacent to the MFC (see Figure 2). Adjust the MFC setpoint to 50%. Ensure that all manufacturer's recommended conditions are met for the MFC. Once the output signals become stable, record the MFC output signal, the flow standard output signal, the ambient and gas temperature, and the gas pressure on the data sheet in Table 1.

11.6 Ensure that the MFC power leads and control signal cables are shielded in the area that will be irradiated by the electromagnetic fields. The cable shielding shall be intact up to the connector. The type of shielding and connector shall be recorded on the data sheet in Table 1.

11.7 *Radiated Electric Field Susceptibility (RS-103)*

11.7.1 *Testing from 10 kHz to 20 MHz*

11.7.1.1 Mount the parallel element antenna on a tripod at a distance of one meter from the MFC and connect the antenna to the audio power amplifier using the 15.25 m (50 ft.) length of RG-58 coaxial cable (see Figure 3). Set the switch to low frequency range.

11.7.1.2 Connect the amplifier input to the signal generator output.

11.7.1.3 Turn on amplifier and signal generator.

11.7.1.4 Using the X10 probe, connect the scope across the antenna terminals.

NOTE 1: It is important to use the X10 probe rather than a coax that terminates in 50 ohms. The audio amplifier will not drive the required voltage into 50 ohms.

11.7.1.5 Set frequency output of the signal generator to 10 kHz.

11.7.1.6 Turn off signal generator modulation and set voltage across the antenna input connector at 35 V rms.

NOTE 2: With this voltage applied to the antenna at frequencies below 1 MHz, the required field strength of 10 V/m at a distance of one meter from the antenna should be established.

11.7.1.7 If, at any frequency, the required voltage cannot be developed across the antenna terminals, set to the maximum possible without exceeding equipment ratings.

11.7.1.8 When voltage is set, turn on modulation and adjust for 50% amplitude modulation with the internal 1 kHz source.

11.7.1.9 Check operation of the MFC in the presence of this radiated field. Record the MFC indicated flow, flow standard output, field strength, and the frequency on the data sheet in Table 1.

11.7.1.10 Before changing frequency as described in ¶¶ 11.7.1.11 to 11.7.1.16, reduce the voltage amplitude to zero.

11.7.1.11 Set frequency to 20 kHz and repeat ¶¶ 11.7.1.6 to 11.7.1.9.

11.7.1.12 Set frequency to 50 kHz and repeat ¶¶ 11.7.1.6 to 11.7.1.9.

11.7.1.13 Set frequency to 100 kHz and repeat ¶¶ 11.7.1.6 to 11.7.1.9.

11.7.1.14 Set frequency to 200 kHz and repeat ¶¶ 11.7.1.6 to 11.7.1.9.

11.7.1.15 Set frequency to 500 kHz and repeat ¶¶ 11.7.1.6 to 11.7.1.9.

11.7.1.16 Set frequency to 1 MHz and repeat ¶¶ 11.7.1.6 to 11.7.1.9.

11.7.1.17 Shut down the test equipment. Then remove the audio amplifier and install RF power amplifier #1 in its place.

11.7.1.18 Having exceeded 1 MHz, turn antenna switch to the high frequency range.

11.7.1.19 Turn on test equipment and resume testing.

11.7.1.20 Set output of the signal generator to 2 MHz and set field strength to 10 V/m, using field strength meter at the controller location.

NOTE 3: If, at any frequency, the required field cannot be developed, set to the maximum possible without exceeding equipment ratings.

11.7.1.21 When voltage is set, turn on modulation and adjust for 50% amplitude modulation with the internal 1 kHz source.

11.7.1.22 Check operation of the MFC in the presence of this radiated field. Record the MFC indicated flow, the flow standard output, and the frequency on the data sheet.

11.7.1.23 Before changing frequency as described in ¶¶ 11.7.1.24 to 11.7.1.26, reduce the field amplitude to zero.

11.7.1.24 Set frequency to 5 MHz and repeat ¶¶ 11.7.1.19 to 11.7.1.22.

11.7.1.25 Set frequency to 10 MHz and repeat ¶¶ 11.7.1.19 to 11.7.1.22.

11.7.1.26 Set frequency to 20 MHz and repeat ¶¶ 11.7.1.19 to 11.7.1.22.

11.7.1.27 After testing at fixed frequencies, sweep the signal source from 50 kHz to 20 MHz at an amplitude of about 35 V rms or 10 V/m. If a malfunction occurs during the sweep, stop and go back to that frequency range and try to find the malfunction by testing at single frequencies. Record the MFC indicated flow, transient response, the flow standard outputs, and the frequency. If the malfunction cannot be found by testing at single frequencies and only shows up when sweeping, the problem is probably that the signal source has to switch ranges at certain frequencies and during the switching can create strong transient noise. Only the results at single frequencies can be trusted; the sweep is only to locate the problems, not to completely define them.

11.7.1.28 Reduce signal source output to zero and de-energize test equipment.

11.7.1.29 Disconnect and remove parallel element antenna.

11.7.2 *Testing from 30 to 200 MHz*

11.7.2.1 Mount biconical antenna on the tripod. Test in a sequence similar to that in ¶¶ 11.7.1.1 to 11.7.1.9.

11.7.2.2 Verify that RF power amplifier #1 is still in place.

11.7.2.3 At a minimum, test at the following frequencies: 30, 40, 50, 60, 70, 80, 90, 100, 120, 140, 160, 180, and 200 MHz.

11.7.2.4 At each frequency, set the field strength to 10 V/m using the field strength meter at the MFC location with the antenna in both the vertical and the horizontal positions.

11.7.2.5 Check operation of the MFC in the presence of the radiated fields generated. Record the MFC indicated flow, the flow standard outputs, and the frequency on the data sheet.

11.7.2.6 After testing at fixed frequencies, sweep the signal source from 30 to 200 MHz. If a malfunction occurs during the sweep, stop and go back to the faulty frequency range and try to find the malfunction by testing at single frequencies. Record the MFC indicated flow, the flow standard outputs, and the frequency on the data sheet. If the malfunction cannot be found by testing at single frequencies and only shows up when sweeping, the problem is probably that the signal source has to switch ranges at certain frequencies and can create strong transient noise during the switching. Only the results at single frequencies can be trusted; the sweep is only to locate problems, not to completely define them.

11.7.2.7 Reduce signal source output to zero and de-energize test equipment.

11.7.3 *Testing from 300 to 990 MHz*

11.7.3.1 Mount the conical log spiral antenna on the tripod. Test in a sequence similar to that in ¶¶ 11.7.1.1 to 11.7.1.9.